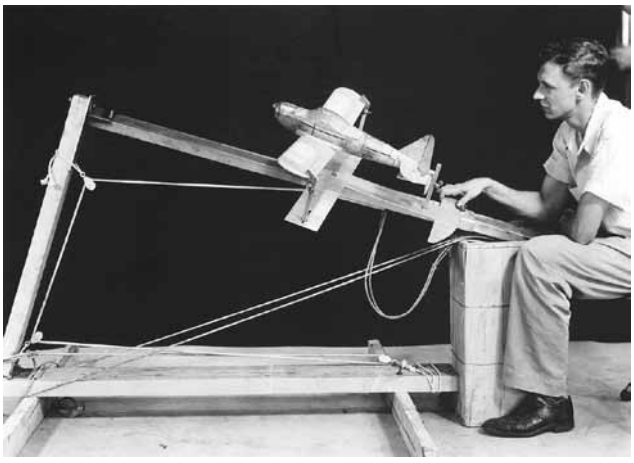
Outdoor Free-Flight Facilities and Ranges

Although the foregoing wind tunnel free-flight testing facilities provide unique and valuable information regarding the flying characteristics of advanced aerospace vehicles, they are inherently limited or unsuitable for certain applications. In particular, vehicle motions for other than 1 g flight involving large maneuvers or out-of-control conditions result in significant changes in flight trajectory and altitude, which can only be studied in the expanded spaces provided by outdoor facilities. In addition, research directed at high-speed dynamic stability and control problems could not be conducted in Langley's low-speed wind tunnels. Outdoor testing of dynamically scaled free-flight models was therefore developed and applied in many research activities at Langley, Dryden, Ames, and Wallops.

Langley Unpowered Drop Models

NASA has used unpowered drop models for a variety of research and development activities involving advanced aircraft and space vehicles. Although these outdoor test techniques are more expensive than are wind tunnel free-flight tests and are subject to limitations because of weather, the results obtained are unique, cannot be obtained in wind tunnels, and are especially valuable for certain types of flight dynamics studies.

One of the most important drop-model applications is in the study of aircraft spin entry motions, which includes analyses of spin resistance and poststall gyrations. A significant void of information exists between the prestall and stall-departure results produced by the wind tunnel free-flight test technique in the Full-Scale Tunnel discussed earlier and the results of fully developed spin evaluations obtained during spin tunnel tests. This information can be critically misleading for some aircraft designs. For example, some aircraft configurations exhibit severe instabilities in pitch, yaw, or roll at stall during wind tunnel free-flight tests, and they may also exhibit potentially dangerous spins, from which recovery is impossible during spin tunnel tests. However, a combination of aerodynamic and inertial properties can result in this same configuration exhibiting a high degree of resistance to enter the dangerous spin following a departure, despite forced spin entry attempts by a pilot. On the other hand, some configurations easily enter developed spins without prolonged assistance from the pilot. Of equal importance, drop-model testing is required to define the most effective control strategies to be used by the pilot of the full-scale aircraft for recovery from out-of-control motions.



Free-flight model of a representative general-aviation airplane being prepared for spin entry tests using a catapult device in 1950. The launching apparatus used an elastic bungee cord to propel the model with preset controls into a stall and incipient spin.

To evaluate the resistance of aircraft to spins, in 1950, NACA Langley revisited the catapult techniques of the 1930s and experimented with an indoor catapult launching technique within the same building (about 70 feet square and 60 feet high) that had earlier housed the 15-Foot Spin Tunnel and the 5-Foot Free-Flight Tunnel.[17] An

elastic bungee cord launched the unpowered model from a launching platform near the ceiling of the building with preset fixed spin entry control settings. Data from the brief flight were recorded with motion pictures, and no instrumentation was carried within the model. A large net stretched across the bottom of the building was used to recover the model after the test flight. This exploratory study was stimulated by the growing requirement to define the spin resistance of radical new configurations of the 1950s and to develop a capability to extend the wind tunnel free-flight tests. Once again, however, the catapult technique proved to be much too cumbersome and limited by testing space, and other approaches to study spin entry were pursued. Although the catapult-launched model was not a primary test technique during modern times, NASA later used it in response to a quick-reaction request from the U.S. Air Force for analysis of spin entry characteristics of the B-58 aircraft, as will be discussed in the next chapter. These tests were conducted in a large airship hangar at the Weeksville Naval Air Facility at Elizabeth City, NC.

Disappointed by the inherent limitations of the catapult-launched technique, the Langley researchers began to explore the feasibility of an outdoor drop-model technique in which models could be launched from a helicopter at much higher altitudes, permitting more time to study the spin entry and the effects of recovery controls. Initially, limited experiments were conducted at Langley Air Force Base in a constrained area to evaluate various schemes for ground-based remote control of the models and methods for coordination of the operation. Encouraged by initial successes, researchers conducted a search to locate a more feasible test site for routine operations. The primary parameters for suitable test sites were a location near Langley and a large drop range away from human inhabitants and dwellings. After additional trials involving model launches from a helicopter at altitudes as high as 2,000 feet at the Patrick Henry Airport in Newport News, VA, the research operations began in 1958 at a low-traffic airport near West Point, VA, about 40 miles from Langley.

As testing progressed at West Point, the technique evolved into an operation consisting of launching the unpowered model at an altitude of about 2,000 feet and evaluating its spin resistance with remotely located, ground-based pilots who attempted to promote spins by various combinations of control inputs and maneuvers. At the end of the evaluations, an onboard recovery parachute was deployed and used to recover the model. The model was retrieved after a ground landing. This test approach proved to be the prototype of an extremely successful testing technique that NASA updated and applied for over 50 years.[18]

Ground control stations for pitch and roll-yaw pilots in early drop model tests. The crew consisted of a pitch pilot, a roll-yaw pilot, and a tracker operator. Binoculars were used for close-in views of the model during flight, and a tracking camera recorded motion pictures of the model's motions.

The drop models used in studies of the mid-1950s represented a tremendous leap in sophistication for free-flight models of the time, as well as significant challenges for model designers and fabricators. The models were large (typically having fuselages of about 7 feet and weighing over 100 pounds) and were constructed of composite

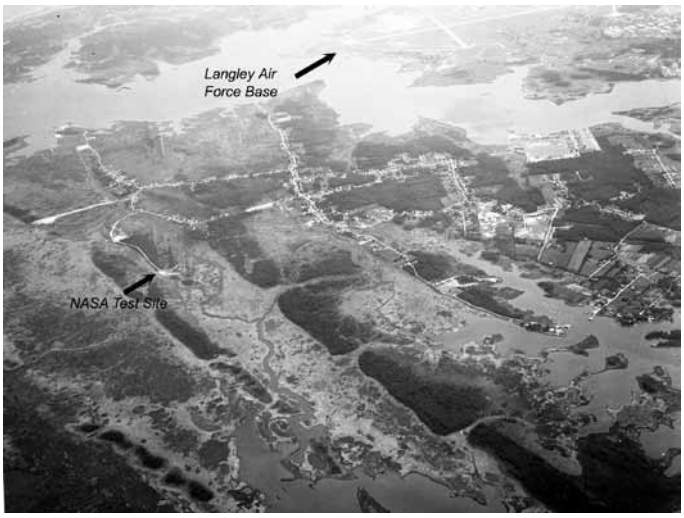
materials to withstand the high g's of ground impact, even when slowed by the recovery parachute. Forward-looking miniature motion-picture cameras were mounted on board the models in flowthrough engine inlets to photograph the positions of flow-direction vanes mounted on a nose boom as well as control position indicator lights mounted on the fuselage interior. The helicopter used for launches at the time experienced considerable turbulence under its fuselage at low forward speeds; therefore, the drop model was mounted at the end of a 5-foot-long extensible vertical shaft and lowered to a position below the helicopter fuselage for launch at a forward airspeed of about 60 knots.

Initially, two separate tracking units consisting of modified power-driven antiaircraft gun trailer mounts were used by two pilots and two tracking operators to track and control the model. One pilot and tracker were to the side of the model's flight path, where they could control the longitudinal motions following launch, while the other pilot and tracker were about 1,000 feet away, behind the model, to control lateral-directional motions. As the technique was refined in later years, a single dual gun mount arrangement was used by both pilots and a single tracker operator.

Drop model of the F-4 fighter mounted on launch helicopter during an evaluation of spin resistance in 1960 at the West Point, VA, airport. After the altitude and speed for launch conditions were satisfied, the model was lowered on a vertical shaft and released.

The success of drop-model testing in predicting spin resistance and spin recovery procedures for military aircraft was disseminated within appropriate Department of Defense (DOD) organizations, resulting in an immediate increase in workload for emerging configurations and an urgency to conduct additional efforts to locate a test site closer to the Langley Research Center for improved efficiency and turnaround time in research projects. Another undesirable characteristic of the West Point operation was the presence of concrete runways, which caused significant damage to models during some landings. In 1959, the Air Force

granted Langley approval to conduct drop tests at the abandoned Plum Tree bombing range near Poquoson, VA, about 5 miles from Langley. The Air Force had cleared the marshy area under consideration of depleted bombs and munitions. Access to the property was negotiated with private citizens, and clearance for the NASA drop operations was monitored and approved by the control tower at Langley Air Force Base (the area was within the flyover zone of aircraft operations at Langley). A temporary building and concrete landing pad for the launch helicopter were added for operations at Plum Tree, and a surge of request jobs for U.S. high-performance military aircraft in the mid- to late 1960s (F-14, F-15, B-1, F/A-18, etc.) brought a flurry of test activities that continued until the early 1990s.



Aerial view of the NASA test site at Plum Tree and its proximity to Langley Air Force Base. The town of Poquoson, VA, is at the right of the photograph. The marshy, soft land was well-suited for drop-model testing and was used for over 30 years.

During operations at Plum Tree, the sophistication of the drop-model technique dramatically increased. High-resolution video cameras were used for tracking the model, and graphic displays were presented to a remote pilot control station, including images of the model in flight and the model's location within the range. A high-resolution video image of the model was centrally located in front of a pilot. In addition, digital displays of parameters such as angle of attack, angle of sideslip, altitude, yaw rate, and normal acceleration were also in the pilot's view. The centerpiece of operational capability was a digital ground-based flight control computer programmed with variable research flight control laws and a flight operations computer with telemetry downlinks and uplinks. The drop models continued to be constructed of composite materials, but the instrumentation was upgraded to include three-axis linear accelerometer packages and three-axis angular rate gyro packages.[19]

A fish-eye camera lens captures a scene of a drop model of the X-31 research aircraft being prepared for a drop as part of poststall and spin resistance studies.

Operations at Plum Tree lasted about 30 years and included a broad scope of investigations for military aircraft configurations, general-aviation configurations, parawings, gliding parachutes, and reentry vehicles. In the early 1990s, however, several issues regarding environmental protection forced NASA to close its

research activities at Plum Tree and remove its facilities. NASA assisted in the restoration of the environment to its current status as a restricted access game preserve. Once again, Langley researchers were forced to identify a suitable test site for future drop-model testing. After considerable searching and consideration of several candidate sites, the NASA Wallops Flight Facility was chosen for Langley's drop-model activities.

The most recent drop tests of a military fighter for poststall studies began in 1996 and ended in 2000. This project, which evaluated the spin resistance of a 22-percent-scale model of the U.S. Navy F/A-18E Super Hornet, was the final evolution of drop-model technology for Langley.[20] Launched from a helicopter at an altitude of about 15,000 feet in the vicinity of Wallops, the Super Hornet model weighed about 1,000 pounds. A camera mounted in the cockpit canopy of the model provided an onboard-pilot's view of the flight, while the remote pilot in command sat in an environmentally controlled room at a pilot station with data displays and video images for input cues. The model included extensive instrumentation to provide data to the flight control computer, the data displays for the drop-model cockpit, and postflight data analysis. Recovery of the model at the end of the flight test was again conducted with the deployment of onboard parachutes. The model used a flotation bag after water impact and was retrieved from the Atlantic Ocean by a recovery boat.

An F/A-18E drop model is launched from a NASA helicopter over the NASA Wallops Flight Facility for spin resistance studies. With a weight of 1,000 pounds, the F/A-18E model was the largest drop model ever tested by Langley researchers.

Dryden Unpowered Drop Models

The legendary contributions of the NASA Dryden Flight Research Center in flight-testing full-scale aerospace vehicles, demonstrators, and hardware have been demonstrated. Nearly every major breakthrough in this Nation's aeronautics legacy occurred there, including flights of the X-1, X-15, Shuttle, lifting bodies, X-43, and spacecraft rescue vehicles. The public may be less familiar with the fact that Dryden researchers have conducted a range of important aerospace projects involving the launching of an unpowered test articles from an airborne vehicle. The following is an overview of approaches used at Dryden during tests of subscale unpowered free-flight models to investigate flight behavior of advanced concepts. Results of specific applications will be covered in a later section.

Water retrieval of the F/A-18E drop model from the Atlantic Ocean after a drop test. The descent by parachute into the water posed special problems for model designers, instrumentation specialists, and the operational crew.